THE ROLE OF EXECUTIVE FUNCTIONING, ANXIETY, AND FAMILY BURDEN ON MATHEMATICAL PERFORMANCE IN CHILDREN WITH TRAUMATIC BRAIN INJURY

A Dissertation

Presented to

The Faculty of the Department

Of Psychology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Doctor of Philosophy

By

Emily C. Maxwell

June, 2015

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Abstract

Mathematical performance is closely linked with anxiety and executive processes, which are both adversely impacted by traumatic brain injury (TBI) in children. The present study examined the impact of executive functioning, anxiety, and family burden of injury on mathematical performance in children with TBI or orthopedic injuries (OI) at 2 months and 2 years post-injury. Participants (ages 6 to 15 years) had been hospitalized for complicated-mild/moderate and severe TBI (n = 51) or OI (n = 47) and were enrolled in a prospective longitudinal study. Children completed two measures of mathematics (calculation and problem solving), and parents completed measures of family burden, anxiety, and executive function. Mediation and path analyses were used to evaluate contributions of the above variables to mathematical outcomes. Compared to children with OI, children with TBI had lower calculation and problem solving scores, higher family burden, and executive functioning impairment persisting 2 years post-injury ($p < 0.05$). Mediation analyses revealed that executive functioning at 2 months partially mediated the role of group on calculation at 2 months (b = -0.71; 95% bootstrap confidence interval CI of -1.93 to -0.06). Problem solving at 2 months and calculation at 2 months mediated the relation of group to problem solving and calculation scores at 2 years post-injury, respectively. Neither anxiety nor family burden significantly impacted mathematical performance ($p < 0.05$). Executive functioning difficulties at 2 months post-injury in children with complicated-mild/moderate to severe TBI predicts long-term functioning and may serve as a red flag regarding the need for interventions to improve educational and psychological health outcomes.

Keywords: pediatric traumatic brain injury, mathematical performance, executive functioning, anxiety, family burden

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Dedication

This dissertation is dedicated to my parents, Ray and Carolyn Maxwell. Thank you both for all your love, support, and encouragement throughout my graduate journey!

The Role of Executive Functioning, Anxiety, and Family Burden on Mathematical Performance in Children with Traumatic Brain Injury

The quality of outcome after pediatric traumatic brain injury (TBI) is influenced by an array of factors. TBI clearly has widespread detrimental effects on brain structure and function (Gennarelli, 1993; Levine et al., 2008; Povlishock & Christman, 1995; Vannorsdall et al., 2010; Xu, Rasmussen, Lagopoulos, & Håberg, 2007). Children with TBI have both volumetric reduction and microstructural changes in white and gray matter (Juranek et al., 2012; Wilde et al., 2005, 2012). Beyond such physical changes, TBI in children also has negative impacts on cognitive abilities (Anderson, Godfrey, Rosenfeld, & Catroppa, 2012; Ewing-Cobbs, Fletcher, Levin, Iovino, & Miner, 1998; Ewing-Cobbs et al., 2004, 2006; Fulton, Yeates, Taylor, Walz, & Wade, 2012; Ganesalingam et al., 2011; Taylor et al., 2008; Yeates et al., 2002). Perhaps as a result, key functional outcomes in children, such as academic performance (Catroppa & Anderson, 1999; Ewing-Cobbs et al., 1998, 2004, 2006; Glang et al., 2008; Jaffe et al., 1992; Taylor et al., 2002), are also adversely affected. In addition, behavioral and emotional difficulties are increased following TBI (Andrews, Rose, & Johnson, 1998; Luis & Mittenberg, 2002), and children in particular are at increased risk for internalizing disorders such as anxiety (Karver et al., 2012; Max et al., 2011). Family burden from the injury is also negatively impacted by TBI (Max et al., 1999; Rivara et al., 1996; Taylor et al., 1999; 2002; Yeates et al., 1997). Few studies, though, address the complex interplay of these outcomes in relation to one another.

The present study sought to fill this gap by evaluating a framework for understanding how the above cognitive, emotional, and environmental factors work together to influence mathematical performance, a critically important outcome after pediatric TBI (Jaffe et al., 1992). Many of these factors are relevant to the process of solving mathematical problems (i.e., which can be complex, multi-step, attentionally demanding, often speeded and/or requiring efficiency, and may also be anxiety provoking). Specifically, we evaluated the pathways through which anxiety, family burden, and executive functions impact mathematical performance after pediatric TBI relative to a group of orthopedic controls (OI). Such information could be used to inform potential future interventions.

In order to properly contextualize the interplay among psychosocial factors on mathematical performance in children with TBI, first we review: (a) the physical ramifications of TBI; (b) cognitive sequelae; (c) academic consequences, particularly with regard to mathematics; (d) emotional changes, and (e) psychosocial factors. This information is then considered with regard to known predictors of mathematical skills (including both cognitive and psychosocial factors) in typically developing children, and then specifically within children with TBI.

Pediatric Traumatic Brain Injury

Importance and physical concomitants in TBI. Injury is the number one cause of death and disability in children and young adults in the United States (Langlois, Rutland-Brown, & Wald, 2006). Every year, TBI accounts for approximately 475,000 pediatric emergency room visits, hospitalizations, and deaths (Langlois et al., 2006) and results in over $1 billion in annual health care expenses (Schneier, Shields, Hostetler, Xiang, & Smith, 2006), with more severe injuries accounting for higher proportion of the costs than less severe injuries. Compared to any other age group, children between the ages 0-4 and 15-19 are more likely to incur a TBI.

Primary injuries to the brain occur at impact and consist of insults such as skull fractures, hemorrhage, contusions, and widespread traumatic axonal injury. The initial injury is accentuated by secondary injuries (e.g., ischemia, hypoxia, hematoma, apoptosis, elevated intracranial pressure, excitotoxic neurotransmitter cascade, and inflammation; Gennarelli, 1993; Povlishock, 2000; Povlishock & Christman, 1995). These primary and secondary injuries can then lead to the disruption of microstructure in both white matter (Levine et al., 2008; Vannorsdall et al., 2010; Xu et al., 2007) and gray matter (Juranek et al., 2012), reducing connectivity between components of neural networks that support cognitive and emotional functions.

Cognitive and academic deficits in TBI. Children with moderate and severe TBI demonstrate considerable cognitive difficulties (Anderson et al., 2012; Ewing-Cobbs et al., 1998, 2004, 2006; Fulton et al., 2012; Ganesalingam et al., 2011; Taylor et al., 2008; Yeates et al., 2002) that persist into adulthood (Cattelani, Lombardi, Brianti, & Mazzucchi, 1998; Nybo, Sainio, & Müller, 2004, 2005). Children with TBI exhibit deficits in verbal skills, spatial reasoning, and constructional skills (Taylor et al., 2008; Yeates et al., 2002). However, the most common neuropsychological impairments in children with TBI include attention, memory, and executive functioning (Beauchamp et al., 2011; Gerrard-Morris et al., 2010; Taylor et al., 2008; van Heughten et al., 2006; Yeates et al., 2002). Of note for the present study, children with TBI demonstrate significant deficits in both parent-reported and performance measures of executive functioning during the initial months of recovery (Taylor et al., 2008; Yeates et al., 2002) and one year post-injury (Sesma, Slomine, Ding, & McCarthy, 2008; Yeates et al., 2002) compared to OI controls. Despite some cognitive recovery, children with TBI continue to show deficits and fail to meet age-expected levels in these areas (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2009). These cognitive skills are important for a host of day-to-day functional skills, and so characterizing these skills has relevance for outcomes in TBI.

Academic skills are one such key functional outcome for children and are impacted by the above cognitive skills. Academically, children with TBI have poorer performance than comparison groups in most academic domains, including word decoding, reading comprehension, mathematics, writing, and spelling (Ewing-Cobbs et al., 2006; Jaffe et al., 1992; Taylor et al., 2002). Not surprisingly, children with severe TBI have more academic difficulties than children with moderate or mild injuries (Catroppa & Anderson, 1999; Ewing-Cobbs et al., 1998, 2004, 2006). These studies also show that in addition to deficits on standardized academic tests, moderate to severe TBI also has a significant impact on academic performance in the classroom and need for support services (Glang et al., 2008). Specifically, receipt of special education services was eighteen times more common in children with moderate and severe TBI (Ewing-Cobbs et al., 2006) than in typically developing children, and the majority of children with severe TBI repeated a grade (Ewing-Cobbs et al., 1998). Given the importance of academic functioning for children in general, and the extent to which it may be compromised in children with TBI, further knowledge in this area is essential for developing appropriate educational programs.

Age at injury appears to play a role in the recovery of academic skills in children with TBI. Ewing-Cobbs and colleagues (2004) found that adolescents with TBI showed greater improvements over time relative to children with TBI in reading recognition and mathematical calculation scores. Additionally, Catroppa et al. (2009) discovered that children with TBI who had been injured at a younger age had lower academic performance than children injured at an older age. Taken together, these studies suggest that children with a younger age at injury have poorer recovery of academic skills over time relative to those injured at an older age. This is likely due to the vulnerable nature of younger children's developing academic skills, whereas the skills of older children are more established (Barnes, Dennis, & Wilkinson, 1999).

Among academic skills, mathematics are particularly impacted relative to other academic skills after TBI (Jaffe et al., 1992). Children with TBI perform worse than controls on mathematical skills, including calculation, word problems, and speed of math fact retrieval (Ewing-Cobbs et al., 2006; Raghubar, Barnes, Prasad, Johnson, & Ewing-Cobbs, 2013; Taylor et al., 2002). Moreover, children with severe TBI have poorer performance in math calculations relative to children with mild or moderate injuries (Catroppa & Anderson, 1999, 2007; Ewing-Cobbs et al. 1998) and do not show as much improvement two years following the injury (Catroppa & Anderson, 1999, 2007). The slower rate of improvement for children with severe TBI puts them at risk for prolonged academic impairments (Jaffe, Polissar, Fay, & Liao, 1995). The consequences of such impairment are significant, as mathematical skills predict success in school, employment, and income within the general population (National Mathematics Advisory Panel, 2008; Rivera-Batiz, 1992; Rose & Betts, 2004). Thus, while academic functioning and mathematics are known to be impacted in child TBI, less is known about how they change, particularly in longitudinal fashion, and even less about how they are situated among the array of physical, cognitive, emotional, and environmental concomitants of TBI.

Emotional difficulties in TBI. Children with TBI demonstrate increased rates of psychiatric problems (Andrews et al., 1998; Bloom et al., 2001; Karver et al., 2012; Luis &

Mittenberg, 2002; Max et al., 2011), which in turn are significantly related to cognitive outcomes (Max et al., 1999). Specifically, there is an increased rate of anxiety following pediatric TBI (Bloom et al., 2001; Karver et al., 2012; Luis & Mittenberg, 2002). Max and colleagues (2011) found that 8.5% of participants had a new anxiety disorder and 17% had subclinical levels of anxiety 6 months post-injury. Children with severe TBI acquired at an earlier age (i.e., preschool and early elementary school) have higher levels and rates of anxiety than children who were injured at an older age (Karver et al., 2012; Max et al., 2011). These higher rates of anxiety have been associated with stressors within the family. For instance, Alway, McKay, Ponsford, and Schönberger (2012) found that higher levels of negative expressed emotion within the family were predictive of higher rates of psychological problems following adult TBI. Additionally, the level of stress after pediatric TBI, as measured by life events that required adjustment, predicted the development of anxiety problems in these children (Luis & Mittenberg, 2002). Despite knowledge about the high rates of anxiety after TBI, there are no known studies focusing on the impact of anxiety on functional outcomes after pediatric TBI, such as mathematical performance. The increase in psychopathology following TBI clearly has significant implications for recovery and functioning, and thus more specific research with an emphasis on anxiety is needed.

Family factors in TBI. TBI is associated with multiple changes in family functioning that include family burden, stress, difficult familial relationships, and poor coping techniques. More specifically, caregivers report high levels of burden (e.g., to worry about the child, changes in the child’s behavior due to the injury, efforts to accommodate to injury-related needs of the child or others; Taylor et al., 1995) and stress following pediatric TBI and continue to experience this distress in the subsequent years following the injury

(Wade, Taylor, Drotar, Stancin, & Yeates, 1998; Wade et al., 2006). Family burden and stress arises after TBI due to several factors such as increased financial commitments, increased time needed to help the child with daily tasks, increased scheduling conflicts due to medical appointments, changes in future goals, and problems managing the child's behavior. Wade et al. (1998) found that caregivers of children with TBI were more likely to report higher levels of stress and burden from the injury than caregivers of children with OI at 6 months and 12 months post-injury. Furthermore, families of children with severe TBI continued to endorse higher rates burden and stress from the injury up to six years post-injury, indicating the significant chronic impact of a severe TBI on family functioning (Wade et al., 2006). Families of children with OI also experience stress from the injury up to 6 months post-injury; however, family burden in this group generally diminishes by one year post-injury (Stancin et al., 2001). Unfortunately, higher levels of stress three years after a child's injury are reported by families that exhibit poorer coping strategies, weaker family relationships, and more symptoms of depression and anxiety (Rivara et al., 1996).

Other family-based factors may also influence the emergence of anxiety following TBI in children. For instance, three years post-injury, parents of children with a moderate or severe TBI continued to endorse feelings of tension related to the child's problem areas that included difficulties with concentration, word-finding, over-dependence, short temper, and forgetfulness (Rivara et al., 1996). Additionally, poor parent psychological functioning and communication has been associated with greater externalizing behavior problems (Raj et al., 2014). However, recent studies have demonstrated the improvement in family factors (e.g., caregiver depressive symptoms, caregiver self-efficacy) through the use of online interventions (Wade et al., 2012, 2014).

Given the connections between family factors and emotional difficulties in children following TBI, evaluating them together in the context of predicting mathematical performance would add needed knowledge. More specifically, family burden is a key area for investigating its role on mathematical performance and its interplay with child anxiety, given the long-standing high levels of burden and anxiety in this population. Interestingly, several of the above cognitive, emotional, and family issues relevant to TBI are also implicated in mathematical skills more generally, which further adds to the potential impact of studying them together.

Mathematical Skills

Domain specific and domain general skills: The role of executive functions. The concomitants of mathematical skills have been viewed from a variety of perspectives, although a dominant concern in the literature has been the relative contributions of domain specific versus domain general skills (Butterworth, 2005). From the domain specific vantage point, mathematical skills are thought to arise from an understanding of quantity and magnitude (Antell & Keating, 1983; Dehaene, Piazza, Pinel, & Cohen, 2003; von Aster & Shalev, 2007), which are then mapped onto the symbolic number system (Ansari, 2008). However, given the acquired nature of TBI, it is unlikely that mathematical problems following injury are the result of disruption to the domain specific magnitude processing system, except to the extent that focal injury damages the parietal networks that have been implicated in number processing (Dehaene et al., 2003). On the other hand, the domain general view emphasizes the role of broader cognitive abilities for mathematics, including language, visual-spatial, declarative memory, processing speed, and the central executive (i.e., attention and working memory; Ayr, Yeates, & Enrile, 2005; Bull & Johnston, 1997;

Geary, 1993, Geary & Hoard, 2005). Moreover, Fuchs et al. (2008) discovered differences in the cognitive predictors of math computations versus math problem solving skills such that word identification, attention, processing speed, and working memory predicted computations, whereas math problem solving was predicted by language, concept formation, nonverbal reasoning, working memory, and attention. Therefore, separate mathematical tasks may have overlapping though separable predictors.

One of the key domain general skills important for mathematics is executive functioning (Geary, 2004). In typically developing children, several executive functions, including working memory, inhibition, shifting, and planning, have been shown to impact and predict future mathematical outcomes (Bull, Espy, & Wiebe, 2008; Espy et al., 2004). Specifically, Espy et al. (2004) found that working memory and inhibitory control predicted early mathematical skills in preschoolers. In addition, Bull et al. (2008) showed that working memory, inhibition, shifting, and planning predicted future mathematical skills in children. The role for executive skills for mathematics makes sense, given the demand characteristics of a given computation and/or applied math problem. For instance, the child needs to plan for how to complete the problem, organize and align the numbers correctly, and then initiate the various steps. The child also has to use inhibition in order to focus on the relevant information of the given problem. While completing the problem, the child uses his or her working memory to remember the steps to complete the problem, while also needing to retrieve specific correct mathematical facts. Finally, the child must monitor his or her performance and check their work.

Unsurprisingly, executive functioning has been shown to be consistently negatively affected after pediatric TBI (Dennis, Guger, Roncadin, Barnes, & Schachar, 2001; Levin &

Hanten, 2005) and is one of the most common impairments following TBI in children (Beauchamp et al., 2011). However, few studies relate executive functioning to mathematical skills in children with TBI, with some exceptions (Arnett et al., 2013; Raghubar et al., 2013). For example, Raghubar et al. (2013) found that mathematical performance was mediated by verbal working memory in children with TBI two years post-injury. Arnett et al. (2013) explored the relation of parent- and self-reported behavior ratings of executive functions (as measured by the Global Executive Composite from the BRIEF) on parent ratings of school competency on the Child Behavior Checklist in children with TBI. They found executive functions to uniquely predict academic performance in the context of other factors such as injury severity, verbal memory, and family socioeconomic status, although that study did not specifically consider measures of emotional or family functioning as additional potential factors in academic outcomes.

It is improbable that impairments in executive function work alone to impact mathematical performance in children after TBI. In fact, there is research that demonstrates the impact of anxiety (Durbrow, Schaefer, & Jimerson, 2001; Grills-Taquechel, Fletcher, Vaughn, Denton, & Taylor, 2012; Ialongo, Edelsohn, Werthamer-Larsson, Crockett, & Kellam, 1994; Normandeau & Guay, 1998; Willcutt & Pennington, 2003) and family burden (Max et al., 1999; Taylor et al., 1999, 2002) on academic outcomes generally, and mathematical outcomes specifically (elaborated below). Therefore, the present study took guidance from the model presented in the Arnett et al. (2013) study, but aimed to extend those findings by evaluating the role of family burden and anxiety, as well as injury related factors, in conjunction with behavioral ratings of executive functions on mathematics performance in pediatric TBI.

Anxiety. Anxiety can impact a child's mathematical performance in a variety of ways. For instance, an anxious child may engage in avoidance behaviors or may complain of "blanking" when asked to complete a mathematical problem. Anxious thoughts may also impact the child's ability to concentrate and focus on the multiple steps involved in completing the task. Finally, the child may second-guess his or her work and change the answer or take random guesses.

Anxiety may be predictive along a trait (i.e., anxiety in all situations) versus state (i.e., anxiety in specific situations) distinction (Sorg & Whitney, 1992). High levels of both trait and state anxiety negatively impact performance on reasoning, visual and verbal working memory, and mathematical tasks (MacLeod & Donnellan, 1993; Miller & Bichsel, 2004). The adverse impact of anxiety on mathematics and academic achievement more generally is apparent for both typically developing children, as well as those with learning difficulties (Ashcraft & Krause, 2007; Grills-Taquechel et al., 2012; Ialongo et al., 1994; Miller & Bichsel, 2004; Wu, Barth, Amin, Malcarne, & Menon, 2012).

Some studies suggest that poorer mathematical performance is only related to math-specific anxiety (Ashcraft & Krause, 2007; Wu et al., 2012), such that high rates of math-specific anxiety negatively impacts more difficult or demanding mathematical problems. Moreover, the rate of math anxiety is significantly higher in children with math disabilities or weaknesses in mathematics (Wu, Willicutt, Escovar, & Menon, 2013). Meanwhile, others find general anxiety to negatively impact not only mathematical performance (Ialongo et al., 1994; Normandeau & Guay, 1998), but other academic areas as well (Durbrow et al., 2001; Ialongo et al., 1994; Normandeau & Guay, 1998; Willcutt & Pennington, 2003), such that higher rates of anxiety are associated with poorer academic performance. Evaluating the role of anxiety in the case of TBI is relevant given that difficulties in mathematics can be selectively and significantly impacted, and that the incidence of anxiety problems following pediatric TBI increases (Bloom et al., 2001; Karver et al., 2012; Luis & Mittenberg, 2002).

Impact of family factors on academic performance. As previously discussed, changes in family functioning, such as family burden and stress, are common following pediatric TBI. Interestingly, these familial factors have been demonstrated to impact academic performance, including mathematical skills. However, stressors in any child's environment can greatly negatively affect his or her academic performance, such that the child may be allotting his or her mental energy towards more pressing issues at hand. One such factor is socioeconomic status and disadvantage, where children from low socioeconomic status families have poorer mathematical performance than children from higher socioeconomic status families (Jordan & Levine, 2009). Of note, children from low-income families are four times less likely to demonstrate growth in number competence over the course of kindergarten and first grade than children from middle-income families (Jordan, Kaplan, Nabors Oláh, & Locuniak, 2006).

Within the context of TBI, the impact of the family environment on the cognitive and academic outcomes has been investigated (Max et al., 1999; Rivara et al., 1996; Taylor et al., 1999; 2002; Yeates et al., 1997), revealing that family dysfunction, family psychopathology or psychological distress, family burden, and lower socioeconomic status all negatively impact cognitive and academic outcomes in children with TBI. Psychosocial disadvantage, family burden, parental distress, and family dysfunction are all associated with negative cognitive and academic outcomes in children with TBI (Max et al., 1999; Taylor et al., 1999).

Specific to mathematical outcomes, it has been found that children with severe TBI who are from a low-stress family environment (as measured by family social stressors and resources) demonstrate recovery of mathematical skills after 12 months post-injury, whereas those children that come from disadvantaged backgrounds remain below the level of children with OI and moderate TBI (Taylor et al., 2002). That study uniquely investigated the impact of family environment specific to mathematical outcomes longitudinally. However, the specific impact of the family burden (as opposed to other family factors and stressors) on mathematical performance over time has not previously been investigated and has not been analyzed in the context of anxiety or executive functioning. Thus, although there are many changes in family functioning after TBI, family burden will be utilized in the present student as an example of one stressor that impacts academics, given the high levels of burden experienced that persist years post-injury.

Interplay between executive functioning, anxiety, and family burden on mathematical performance. The aforementioned research has demonstrated that family functioning, as well as the emergence of anxiety after injury, can impact cognitive and academic outcomes after TBI. Moreover, prior literature has established that children with TBI are more likely to have higher rates of anxiety and lower mathematical performance following injury. Although anxiety in typically developing children has been shown to negatively impact mathematical performance, there have been no studies investigating the role of anxiety on mathematical outcomes in children with TBI. Additionally, this relationship has not been examined in the context of the family burden of injury. Thus, more research is needed to further understand the collective impact of these factors on mathematical performance in children with TBI.

While there is no current model evaluating the role of each of these factors simultaneously, there are a handful of studies to examine at least two of these factors on mathematical performance in typically developing individuals, one of which focused on TBI. Eysenck, Derakshan, Santos, and Calvo (2007) emphasize that anxiety can negatively impact executive functions such as inhibition and switching, which are important for working memory. Ashcraft and Kirk (2001) found that students with high levels of math anxiety had lower performance on a working memory task, which in turn negatively impacted their performance on a mathematical task. In children with TBI, Arnett et al. (2013) provided insight as to how executive functions (with socioeconomic status, verbal learning, and injury severity) operate to impact school performance, as indicated by parent ratings of school competence. The present study built upon the work of Arnett et al. (2013) by examining the role of executive functions on direct performance measures of academic skills, as well as by anticipating contributions from anxiety and family burden.

The Present Study

The present study evaluated mathematical performance in children with complicated-mild, moderate, and severe TBI compared to children with OI at 2 months and 24 months post-injury, while considering anxiety, parent-rated executive functioning, and parent-rated burden of injury. Although mathematical performance has not been shown to differ over the time course of 2 to 24 months post-injury for children with TBI (Raghubar et al., 2013), performance was below that of controls at both time points, and it is unclear if there are different patterns of predictors at these early and late time points. If high anxiety and high family burden have a negative impact on mathematical performance, then treatment for anxiety and increasing social support for children with TBI will need to be prioritized, even if the primary target of intervention is mathematical. Thus, the primary goal of the present study was to understand the interplay of various predictors (i.e., executive functioning, anxiety, and family burden) on mathematical outcomes in hopes of establishing a foundation to develop a model of academic recovery following pediatric TBI.

Four hypotheses were examined. The first three sought to provide additional evidence for the impact of TBI on executive functioning, anxiety, and family burden, respectively. An advantage of the present study was the evaluation of these factors, all within the same sample. The final hypothesis integrated what is known about these individual factors with mathematical performance over time, to more fully understand their interplay in a more direct, model-building manner:

1. Parent-reported executive functioning in children with TBI will be similar to children with OI at 2 months, reflecting current dysfunction at that time point. However, at 24 months post-injury, children with TBI are expected to have worsened in their executive functioning, while the children with OI are expected to have an improvement in their executive functioning, resulting in a group by time interaction. Such late emerging difficulties in executive functioning have been observed in earlier studies (Dennis et al., 2001; Levin & Hanten, 2005).
2. Overall anxiety will be clinically elevated in both children with TBI and those with OI at 2 months post-injury. However, over the course of 2 years (24 months post-injury), the level of overall anxiety is expected to *increase* for children with TBI and *decrease* for children with OI to the normative range, resulting in significant group differences at the later time point, as seen through earlier studies (Karver et al., 2012; Luis & Mittenberg, 2002). Therefore, a group by time interaction is anticipated.

3. Family burden will be similar and elevated in both children with TBI and those with OI at 2 months, and decrease in both groups from 2 months to 24 months post-injury, though with a larger decrease in the OI group. This pattern is consistent with previous research (Rivara et al., 1996; Wade et al., 1998). Again, a group by time interaction is expected.
4. Mediation models will identify the relative predictive extent of the above factors within and across time, and how they operate together to impact mathematical performance at 24 months post-injury. Age at injury will be included as a covariate in these models and is expected account for significant variance, such that younger children will have poorer mathematical outcomes than older children. Additionally, while we hypothesize that family burden will play a role in mathematical performance at 24 months post-injury (see hypothesis 4a2), it is anticipated that the role of anxiety will be stronger (and thus used in hypothesis 4c, in conjunction with executive function). Finally, when assessing mathematical performance at 24 months post-injury, it is anticipated that the impact of executive functioning, anxiety, and family burden will each be stronger when assessed at 24 months post-injury, rather than 2 months post-injury. Thus, only 24-month indicators of executive function, anxiety, and burden are planned for use in hypothesis 4a2, 4b2, and 4c; however, mathematical performance at 2 months is included in all models. These models are summarized below:
    a. Executive Function: (1) The effect of group on mathematical performance at 2 months post-injury will be mediated by the level of executive functioning at 2 months post-injury, such that impact of group will be diminished, and

lower levels of executive functioning will be associated with lower mathematical performance. (2) Similarly, the effect of group on mathematical performance at 24 months post-injury will be mediated by the level of executive functioning at 24 months post-injury, as well as mathematical performance at 2 months post-injury. These relationships are anticipated based on previous research that has conducted path analyses including the effect of executive functioning on academic performance (Arnett et al., 2013).

b. Child Anxiety and Family Burden: (1) The effect of group on mathematical performance at 2 months post-injury will be mediated by the level of family burden and child anxiety at 2 months post-injury, such that the group difference in math will be ameliorated with these factors considered, and with higher levels of family burden and anxiety associated with lower mathematical performance. (2) Similarly, the effect of group on mathematical performance at 24 months post-injury will be mediated by the level of family burden and child anxiety at 24 months post-injury, as well as mathematical performance at 2 months post-injury. Such a finding would support prior studies that have shown that negative expressed emotion and higher levels of stress predict the development of anxiety in individuals with TBI (Alway et al., 2012; Luis & Mittenberg, 2002) and that anxiety negatively impacts mathematical performance in children (Ashcraft & Krause, 2007; Wu et al., 2012, 2013).

c. A heuristic will be examined that is informed by and elaborates upon the findings in hypotheses 4a and 4b (see Figure 1). The variables are placed in the model according to temporal precedence. Overall, the effect of group on mathematical performance at 24 month post-injury will be mediated by mathematical performance at 2 months post-injury, as well as the level of executive functioning, anxiety, and family burden, at 24 months post-injury. We also examined nested models that proposed only indirect effects of group on mathematical performance at 24 months post-injury, which follow from the results of hypotheses 4a and 4b.

Methods

Participants. Participants were comprised of children ages 6 to 15 years of age at the time of injury and were recruited from those who were admitted to the Pediatrics Trauma Service at the Level 1 Pediatric Trauma Center at Children's Memorial Hermann Hospital for TBI (*n* = 60) and OI (*n* = 55). OI were chosen to examine differences between children who have experienced brain injury versus injury to other body regions, given that both children with TBI and OI have endured a traumatic injury and received medical treatment. Additionally, research has suggested that children who sustain injuries exhibit more learning and behavioral difficulties than children who do not sustain injuries (Bijur & Hasum, 1995). The families of injured children are also more likely to endure social disadvantage and stress (Howard, Joseph, & Natale, 2005; Parslow, Morris, Tasker, Forsyth, & Hawley, 2005). Thus a healthy, non-injured comparison group was not utilized in the present study.

The TBI group consisted of children who experienced acceleration-deceleration or blunt impact injuries, resulting in complicated-mild (*n* = 2), moderate (*n* = 11), or severe (*n*

= 47) TBI. Severity of TBI was determined using the lowest post-resuscitation Glasgow Coma Scale (GCS) score (Teasdale & Jennett, 1974), where severe TBI was a score of 3-8 and moderate TBI was a score of 9-12. Complicated-mild TBI was classified as a GCS score of 13-15 and acute hemorrhage or parenchymal injury seen in neuroimaging (Levin et al., 2008). For all analyses, the TBI group was separated into two groups. Complicated-mild and moderate injuries comprised a single group, while severe injuries comprised the second. The TBI group was subdivided given past research documenting differences in academic and familial outcomes amongst different TBI severity levels (Catroppa & Anderson, 1999; Ewing-Cobbs et al., 1998, 2004, 2006; Wade et al., 2006).

The OI comparison group consisted of children who did not experience any facial injuries, but were hospitalized for skeletal and/or bodily injuries after an accident. This population was chosen to account for the stressors that accompany injury, including hospitalization. OI participants with IQ scores of 120 or greater were also excluded from the study. Participants from either group were excluded for: 1) major developmental or psychiatric disorders that would confound assessment of the impact of injury on outcomes (e.g., autism, mental retardation); 2) pregnancy; and 3) history of abuse or domestic violence.

All participants were in a prospective longitudinal study. Informed written consent was obtained from the child's parent or legal guardian. Written assent was also received from children ages 8 years and older, in accordance with the guidelines established by the Institutional Review Board at the University of Texas Health Sciences Center at Houston. Data security and analyses were completed in accordance with the Institutional Review Board at the University of Houston. Participants were given all measures at baseline (2 months post injury +/- 1 week). They also returned for subsequent testing at 6, 12, 18, and 24 months post injury.

Given the relatively small sample size of the study, participants with available data for each analysis were included, resulting in varying sample sizes across analyses. The initial sample consisted of 60 children with TBI (13 complicated-mild/moderate, 47 severe) and 55 children with OI. The subset that contained mathematical outcomes at both time points consisted of 55 children with TBI (13 complicated-mild/moderate, 38 severe) and 47 children with OI. For the OI group, there were no differences between those children that completed mathematical measures at both time points compared to those that did not have both time points completed on age at injury, gender, mother's education, executive functioning, child- and parent-rated anxiety, family burden, or mathematical outcomes. For the TBI group, there were no differences between those children that completed mathematical measures at both time points compared to those that did not have both time points completed on gender, mother's education, executive functioning, or child- and parent-rated anxiety. However, for the children in the TBI group that did not complete mathematical measures at both time points, they had significantly higher ages at injury, higher rates of family burden at 12 and 24 months post-injury, and lower Calculation scores at 24 months post-injury.

Measures. Injury severity within the TBI group was assessed using the lowest post-resuscitation Glasgow Coma Scale (GCS) score (Teasdale & Jennett, 1974). Classification as severe TBI was a score of 3 to 8, whereas moderate TBI was a score of 9 to 12. Complicated-mild TBI was classified as a GCS score of 13-15 and acute hemorrhage or parenchymal injury seen in neuroimaging, in line with previous accepted criteria (Levin et al., 2008).

Maternal education was assessed as part of the Hollingshead 4-Factor Scale (Hollingshead, 1975), which is a measure used to determine socioeconomic status by self-reported parental education and occupation status. Maternal education was utilized in the present study given that parental education tends to remain stable over time (Sirin, 2005). Furthermore, maternal education was chosen over paternal education due to their high correlation and that maternal education is more often reported for single-parent families (Entwislea & Astone, 1994).

To assess the participants' executive functioning, parents completed the Behavior Rating Inventory for Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). The use of this questionnaire was chosen over performance measures of executive functioning due to its ecological validity (Gioia & Isquith, 2004). Parent report, rather than self-report, was used given that previous research has suggested that parent ratings of executive functioning on the BRIEF are more objective than self-ratings (Arnett et al., 2013). This measure has been found to have high internal consistency (0.80-0.98), good test-retest reliability (0.81), and good convergent and divergent validity (Gioia & Isquith, 2004). The BRIEF has been noted by experts to be one of the core data elements in pediatric TBI research and has been found to be sensitive to the effect of TBI (McCauley et al., 2012). The Global Executive Composite will be used in the analyses to be consistent with previous studies (Arnett et al., 2013) and to provide a single value of general executive functioning for the multivariate analyses given the study's relatively small sample size. Scores of 65 or higher are considered clinically significant (Gioia et al., 2000).

To determine the child's level of anxiety, the participants completed the Screen for Child Anxiety Related Emotional Disorders (SCARED) (Birmaher et al., 1997). This questionnaire will help to determine participants' overall level of anxiety, and the scale also assesses specific areas of anxiety including: Panic/Somatic, General Anxiety, Separation Anxiety, Social Phobia, and School Avoidance. The total raw score will be utilized in the analyses, as it is suspected that anxiety in any domain could impact the recovery of mathematical skills. Clinically, a raw score of 25 or higher may indicate the presence of an anxiety disorder (Birmaher et al., 1999). This cutoff score was determined by comparing scores in a sample of children with anxiety disorders from children with non-anxiety psychiatric disorders. It has been shown to exhibit good internal consistency (0.79-0.87) and test-retest reliability (0.60-0.90) and discriminant validity (Birmaher et al., 1999). Self-reported anxiety is preferred over parent-reported due to previous research demonstrating low correlations between parent- and self-rated anxiety (Langer, Wood, Bergman, & Piacentini, 2010; Manassis, Tannock, & Monga, 2009) and parental under-reporting of internalizing symptoms (Levi & Drotar, 1999). However, given that the SCARED was not administered at 24 months post-injury, both child-reported and parent-reported measures were investigated in the analyses. This measure has been indicated as a beneficial measure in pediatric TBI research by leading experts in the field (McCauley et al., 2012). The total raw, un-normed score will be used in the analyses.

Parent-reported anxiety was assessed using the Anxiety Problems subscale from the Child Behavior Checklist (CBCL; Achenbach, 2001). It has been shown to exhibit good test-retest reliability (0.80; Achenbach, 2001) and discriminant validity (Nakamura, Ebesutani, Bernstein, & Chorpita, 2009). This measure was chosen due to its wide use of problem behaviors that emerge or continue after TBI. This subscale is comprised of 6 items assessing symptoms of anxiety. Age-normed *T* scores were used in the analysis and scores of 65 or higher are considered clinically significant (Achenbach, 2001).

Parents completed a questionnaire based on the Family Burden of Injury Interview (FBII; Taylor et al., 1995) to determine family burden related to the child's injury. Item responses range from 0 (not at all stressful) to 4 (extremely stressful). The FBII in interview form has been previously administered in several studies of TBI recovery (Taylor et al., 1999, 2001; Wade et al., 2003, 2004) and has been deemed as useful measure in TBI research by leading experts in pediatric TBI as part of the Common Data Elements Workshop (McCauley et al., 2012). It has been shown to exhibit good internal consistency (0.90) and split-half reliability (0.80). This measure has shown group differences between severe and moderate injuries. Additionally, research has demonstrated its predictive ability on child functioning after injury (Burgess et al., 1999). In determining the scores to be utilized in the analyses, some of the items were not relevant to each family (e.g., questions related to spouses or siblings). Thus, in order to place all participants' scores on the same scale, the average un-normed score of the applicable items for each participant from the FBII will be used in the analyses.

Mathematical performance was assessed with the Calculation and Applied Problems subtests of the Woodcock-Johnson III (WJ-III; Woodcock, McGrew, Mather, & Schrank, 2001). During the Calculation subtest, participants were asked to complete written arithmetic computations using paper and pencil. For Applied Problems, subjects were given paper and pencil to solve oral word problems. These measures have been found to have excellent reliability and validity, have been used in numerous studies of pediatric TBI

(Ewing-Cobbs et al., 2006, 2008; Taylor et al., 2008), and have been promoted to be used in TBI research by pediatric TBI experts (McCauley et al., 2012). All analyses utilizing mathematical performance were run separately for Calculation and Applied Problems subtests. This approach was taken given that previous studies have found differential impacts of cognitive predictors on math calculations versus problem solving (Fuchs et al., 2008). Thus, the interplay of anxiety, family burden, and executive functioning may differ for Calculation versus Applied Problems.

Procedure. Participants were seen on an outpatient basis at 2, 6, 12, and 24 months post-injury. At each time point, they were administered a comprehensive neuropsychological evaluation, which included measures that were not the focus of the present investigation. For measures relevant to the present study's primary aims, participants were administered the following measures at 2 months post-injury: SCARED, CBCL, BRIEF, FBII, and WJ-III Calculation and Applied Problems. These measures were repeated at 12 and 24 months post-injury, with the exception of WJ-III Calculation and Applied Problems at 12 months post-injury and SCARED at 24 months post-injury.

Analytic Approach

Analyses for Hypotheses 1, 2, and 3 were evaluated within the general linear models (GLM) framework, specifically utilizing repeated measures analysis of variance (ANOVA). These analyses are considered mixed models given the presence of one between-subjects variable (group) and one within-subjects variable (time). For each analysis, there were three groups and three time points (except for analysis involving child-rated anxiety which only had two time points). Where group effects were significant, a priori follow-up analyses were evaluated, with the expectation that both TBI groups would have poorer executive functioning and higher levels of anxiety and family burden compared to the OI group. Additionally, it was expected that the severe TBI group would have poorer executive functioning and higher levels of anxiety and family burden compared to the complicated-mild/moderate TBI group. Assumptions of repeated measures ANOVA include normal distribution, sphericity, and randomness. Values of skewness and kurtosis were obtained to assess the normality of all variables. Outliers in any of the variables were identified and explored to ensure that they are merely extreme values and not special cases or errors. Three OI controls appeared to be outliers in terms of parent-rated anxiety and family burden, as well as one additional OI control appeared to be an outlier for family burden. Analyses were evaluated with and without these individuals. Reported results reflect inclusion of these outliers given the consistency in the findings. Any violations for the assumption of sphericity were corrected via the Greenhouse-Geisser correction (Hays, 1994). Participants for the present study were not pre-selected or analyzed by family or school unit, and so the independence assumption for these analyses can be assumed.

Multiple mediation was utilized to reveal conditional indirect and total effects for Hypotheses 4a and 4b (Preacher & Hayes, 2008). Mediation occurs when a variable affects the outcome variable indirectly through one or more intervening variables. To analyze the components of Hypothesis 4, we explored whether group (complicated-mild/moderate TBI, severe TBI, and OI) influences mathematical performance directly or indirectly through earlier mathematical performance as well as concurrent executive functioning, anxiety, and/or family burden. Thus the following was investigated via multiple mediation: the effect of group on mathematical performance without the mediator(s) (path c), the direct effect of group on mathematical performance with the mediator(s) (path c′), and the indirect effect of group on mathematical performance via each of the mediators (the product of the sub-paths). The mediators in these analyses included Family Burden of Injury total scores, SCARED total scores, the Global Executive Composite score on the BRIEF, and Woodcock-Johnson III 2 month post-injury score (for Hypothesis 4a2 and 4b2). Bootstrapping, a procedure which repeatedly samples from the data and estimates the indirect effects of each resample dataset, was implemented to obtain the upper and lower limits of a 95% confidence interval while testing for mediation (Preacher & Hayes, 2008). Bootstrapping is preferred over Sobel tests (Preacher & Hayes, 2008) given that Sobel tests incorrectly assume the normal distribution of the indirect effect. Additionally, the bootstrapping procedure has higher power while controlling for Type 1 error (Mackinnon, Lockwood, & Williams, 2004; Preacher & Hayes, 2004, 2008).

To analyze Hypothesis 4c, path analysis was utilized to examine the possible causal relationships between the variables considered for mathematical performance in children with TBI. The assumptions of path analysis include no measurement error and no specification error. They also include the assumptions of regression – that all relations are linear and additive, statistical independence, homoscedasticity (i.e., the variance of the errors is the same across all levels of the independent variable), and normality of the error distribution. The correlations between predictors were also examined prior to path analysis so as to avoid high multicollinearity (Klem, 1995).

All the recursive models (i.e., models in which the causal path is unidirectional) included group (OI or TBI), the Global Executive Composite score on the BRIEF at 24 months post-injury, SCARED total raw score at 12 months post-injury, CBCL Anxiety Problems *T* score at 24 months post-injury, and the primary outcomes, Woodcock-Johnson

III Calculation /Applied Problems (2 months post-injury and 24 months post-injury). Separate models were used to evaluate the primary outcomes at 24 months post-injury. Path coefficients were calculated from model based covariance matrices using maximum likelihood estimation, and global and local model fit was assessed with the Chi-Square Test of Model Fit, Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), and Standardized Root Mean Square Residual (SRMR). A good model fit is indicated by an insignificant Chi-Square test ($p > 0.05$), RMSEA values of < 0.06, CFI of $\geq$ 0.95, and SRMR < 0.05 (Barrett, 2007; Hooper, Coughlan, & Mullen, 2008; Hu & Bentler, 1999).

For all analyses, we considered important demographic and medical covariates when examining performance specific to children with TBI in order to further understand the factors and mechanisms of mathematical performance. Age at injury was considered as a potential covariate for all models. Additionally, it was likely that mother's education would be correlated with mathematical performance; thus, SES as measured by mother's level of education was evaluated as a potential covariate. For all analyses, two contrasts were constructed such that each of the TBI groups (complicated-mild/moderate and severe) was compared to the OI group. Models first included group as the independent variable, and the role of each covariate was examined. Given the study's sample size and number of variables in the hypothesized models, we strove to balance the inclusion of covariates with parsimony, and thus only robust, relatively unrelated covariates were included in the models.

A covariate was included if there is a significant correlation between the variable and the outcome measures for both groups together or for TBI only. This was the case for age at injury, and mother's education. Age at injury was included for analyses involving mathematical outcomes, executive functioning child-rated anxiety, and family burden. Mother's education was included for analyses involving mathematical outcomes. Preliminary analyses indicated low intercorrelations among these covariates. The results below include the relevant covariates. If a covariate was not contributory, the variable was still included in the analysis.

Results

Table 1 provides demographic and injury information for all participants. Table 2 displays the means and standard deviations on predictors (executive function, anxiety, and family burden) as well as mathematical outcomes, for each time point, by group. Table 3 shows the correlations between predictor variables, mathematical outcomes, and covariates for the TBI group.

Hypothesis 1: Executive functioning. Repeated measures ANOVA was used to determine differences between children with TBI (complicated-mild/moderate and severe) and children with OI on executive functioning over time. Group was the between-subjects factor and executive functioning was the within-subjects factor. This model included age as a covariate, but it was not contributory ($p > 0.05$). There was a significant effect for group, $F(2, 81) = 9.02$, $p < 0.001$, such that at 2, 12, and 24 months post-injury, the severe TBI group had significantly higher ratings of executive functioning difficulties on the BRIEF than the OI group. At 2 and 12 months post-injury, the complicated-mild/moderate TBI group also had significantly higher ratings of executive dysfunction than the OI group. The complicated-mild/moderate TBI and severe TBI groups were not different from each other at any time point. There was not a significant effect for time, $F(2, 162) = 1.36$, $p = 0.259$, or for the interaction between group and time, $F(4, 162) = 0.64$, $p = 0.634$. Despite group differences, the mean scores of both the TBI groups and the OI group were not in the clinically elevated levels of executive functioning difficulties at any time point.

Hypothesis 2: Anxiety. Repeated measures ANOVA was used to determine differences between children with TBI (complicated-mild/moderate and severe) and children with OI on measures of anxiety (child-rated or parent-rated) over time. Group was the between-subjects factor and anxiety was the within-subjects factor.

Child report. Age at injury was a relevant covariate and was included in the analyses. There was an effect for age, $p < 0.001$, such that lower ages were associated with higher rates of anxiety. However, there were no effects for group, $F(2, 97) = 0.09$, $p = 0.910$, for time, $F(1, 97) = 1.14$, $p = 0.289$, or their interaction, $F(2, 97) = 0.88$, $p = 0.418$ on SCARED scores. Of note, at 2 months post-injury, 48% of the OI group, 38% of the complicated-mild/moderate TBI group, and 45% of the severe TBI group had clinically significant levels of anxiety. Additionally, at 12 months post-injury, 43% of the OI group, 46% of the complicated-mild/moderate TBI group, and 32% of the severe TBI group had clinically significant levels of anxiety.

Parent report. There were no relevant covariates included in these analyses. The effect for group was not significant, $F(2, 82) = 1.83$, $p = 0.167$. There was a significant effect for time, $F(2, 164) = 3.93$, $p = 0.021$, such that all groups had significantly higher ratings of anxiety at 2 months compared to 12 months and 24 months ($p < 0.040$). There was no significant difference in the ratings of anxiety at 12 months compared to 24 months ($p > 0.050$). There was no significant interaction between group and time, $F(4, 164) = 0.72$, $p = 0.580$. At 24 months post-injury, the severe TBI group had significantly higher ratings of anxiety compared to the controls ($p = 0.016$). The complicated-mild/moderate TBI group was not significantly different from the severe TBI group or the controls. However, mean scores of anxiety ratings for neither the TBI groups (complicated-mild/moderate, severe), nor the OI group, were in the clinically elevated range at any time point.

Hypothesis 3: Family burden. Repeated measures ANOVA was used to determine differences between children with TBI (complicated-mild/moderate and severe) and children with OI on family burden over time. Group was the between-subjects factor and family burden was the within-subjects factor. The model included age at injury, but it was non-contributory ($p > 0.050$). There was a significant effect for group, $F(2, 77) = 6.14$, $p = 0.003$, such that children with severe TBI had higher ratings of family burden at 12 and 24 months post-injury compared to controls ($p < 0.001$); the complicated-mild/moderate TBI group was not significantly different from the severe TBI group or the controls at any time point. There was not a significant effect for time, $F(2, 154) = 0.77$, $p = 0.465$, or for the interaction between group and time, $F(4, 154) = 1.53$, $p = 0.197$. However, the effect size data indicated that the relative difference between groups was larger for 24 months (severe TBI vs. OI d = 1.13, complicated-mild/moderate TBI vs. OI d = 0.54) relative to 12 months (severe TBI vs. OI d = 0.81, complicated-mild/moderate TBI vs. OI d = 0.26) and 2 months (severe TBI vs. OI d = 0.38, complicated-mild/moderate TBI vs. OI d = 0.03). The levels of burden amongst the groups were somewhat lower than the levels reported in Wade et al. (1998), but were most consistent with the levels reported in Wade et al. (2006). Of note, the severe TBI group exhibited high levels of family burden across all time points at similar levels as these previous studies.

Hypothesis 4A: Mediation models of group effects on math via executive functioning. Table 4 provides the parameters for the indirect effects of the mediation models. For all analyses age at injury and mother's education were included in the models.

Applied Problems. At 2 month post-injury, when executive functioning was included in the model, the total effect of group on Applied Problems was significant ($p < 0.001$), as was the direct effect of group on Applied Problems ($p = 0.001$). The indirect effect of group on Applied Problems at 2 months post-injury via executive functioning was not significant, suggesting no mediation.

For Applied Problems at 24 months post-injury, with executive functioning at 24 months and Applied Problems at 2 months post-injury included in the model, the total effect of group on Applied Problems at 24 months post-injury was significant ($p = 0.002$); however, the direct effect of group on Applied Problems at 24 months post-injury was not ($p = 0.929$). The indirect effect for executive functioning at 24 months post-injury was not significant, but the indirect effect for earlier Applied Problems was significant (point estimate = -3.92, 95% bootstrap CI = -6.10 to -1.91).

In summary, executive functioning did not mediate the relations of group with Applied Problems at 2 or 24 months post-injury. At 24 months, earlier Applied Problems (at 2 months) mediated the relation of group to Applied Problems.

Calculation. For 2 months post-injury, when executive functioning was included in the model, the total effect of group on Calculation was significant ($p < 0.001$), as was the direct effect of group on Calculation ($p < 0.001$). The indirect effect was significant with a point estimate of -0.71 and a 95% bootstrap CI of -1.93 to -0.06; thus the effect of group on Calculation at 2 months post-injury was partially mediated by executive functioning.

At 24 months post-injury, when executive functioning at 24 months and Calculation at 2 months post-injury were included in the model, the total effect of group on Calculation at 24 months post-injury was significant ($p = 0.001$); however, the direct effect of group on Calculation at 24 months post-injury was not ($p = 0.894$). The indirect effect of group on Calculation at 24 months post-injury was mediated by Calculation at 2 months post-injury (point estimate = -4.83, 95% bootstrap CI = -7.23 to -2.68). Unlike the results for 2 months post-injury, the indirect effect for executive functioning was not significant.

In summary, executive functioning at 2 months post-injury partially mediated the relations of group on Calculation performance at 2 months post-injury. However, Calculation at 2 months post-injury mediated the relation of group on Calculation performance at 24 months post-injury, while executive functioning at 24 months post-injury did not mediate the relation.

Overall, executive functioning did not mediate the effect of group on Applied Problems at either time point. It did, however, mediate the effect of group on Calculation at 2 months post-injury. For both math skills, performance at 2 months post-injury completely mediated the effect of group on mathematical performance at 24 months post-injury.

Hypothesis 4B: Mediation models of group effects on math via anxiety and family burden. Table 4 provides the parameters for the indirect effects of the mediation models. For all analyses, age at injury and mother's education were included in the models.

Applied Problems.

Child-rated anxiety and family burden. At 2 months post-injury, the total effect of group on Applied Problems was significant ($p = 0.002$), as was the direct effect of group on Applied Problems ($p = 0.003$). None of the indirect effects of child rated anxiety and family burden was significant, thus the effect of group on Applied Problems at 2 months post-injury was not mediated by child-rated anxiety or family burden.

For 24 months post-injury, when 24 month child-rated anxiety, family burden, and Applied Problems at 2 months post-injury were included in the model, the total effect of group on Applied Problems at 24 months post-injury was significant ($p = 0.015$); however, the direct effect of group on Applied Problems at 24 months post-injury was not significant ($p = 0.939$). Group had a significant indirect effect on Applied Problems at 24 months post-injury through its effect on Applied Problems 2 months post-injury with a point estimate of -3.39 and a 95% bootstrap CI of -5.94 to -1.36.

Parent-rated anxiety and family burden. When parent-rated anxiety and family burden were included in the model, the total effect of group on Applied Problems was significant ($p < 0.001$), as was the direct effect of group on Applied Problems ($p = 0.001$). None of the indirect effects was significant, thus the effect of group on Applied Problems at 2 months post-injury was not mediated by parent-rated anxiety or family burden.

When 24 month parent-rated anxiety, family burden, and Applied Problems at 2 months post-injury were included in the model, the total effect of group on Applied Problems at 24 months post-injury was significant ($p = 0.006$); however, the direct effect of group on Applied Problems at 24 months post-injury was not ($p = 0.984$). Group had a significant indirect effect on Applied Problems at 24 months post-injury through its effect on Applied Problems 2 months post-injury with a point estimate of -3.83 and a 95% bootstrap CI of -6.50 to -1.74.

In summary, for Applied Problems the significant effect of group on mathematical performance at 2 months post-injury was not mediated by anxiety (child-rated or parent-rated), or by family burden. However, the significant effect of group on mathematical performance at 24 months post-injury was mediated by Applied Problems at 2 months post-injury.

Calculation.

Child-rated anxiety and family burden. For 2 months post-injury, when child-rated anxiety and family burden were included in the model, the total effect of group on Calculation was significant ($p < 0.001$), as was the direct effect of group on Calculation ($p < 0.001$). None of the indirect effects was significant, thus the effect of group on Calculation at 2 months post-injury was not mediated by child-rated anxiety or family burden.

For 24 months post-injury, when child-rated anxiety, family burden, and Calculation at 2 months post-injury were included in the model, the total effect of group on Calculation at 24 months post-injury was significant ($p = 0.002$); however, the direct effect of group on Calculation was not ($p = 0.709$). Group had a significant indirect effect on Calculation at 24 months post-injury through its effect on Calculation 2 months post-injury with a point estimate of -4.91 and a 95% bootstrap CI of -7.87 to -2.79.

Parent-rated anxiety and family burden. When parent-rated anxiety and family burden were included in the model, the total effect of group on Calculation was significant ($p < 0.001$), as was the direct effect of group on Calculation ($p < 0.001$). None of the indirect effects was significant, thus the effect of group on Calculation at 2 months post-injury was not mediated by parent-rated anxiety or family burden.

When parent-rated anxiety, family burden, and Calculation at 2 months post-injury were included in the model, the total effect of group on Calculation at 24 months post-injury was significant ($p = 0.001$); however, the direct effect of group on Calculation was not ($p =

0.294). Group had a significant indirect effect on Calculation at 24 months post-injury through its effect on Calculation 2 months post-injury with a point estimate of -3.01 and a 95% bootstrap CI of -5.34 to -1.38.

In summary, for Calculation the significant effect of group on mathematical performance at 2 months post-injury, was not mediated by anxiety (child-rated or parent-rated), or by family burden. However, the significant effect of group on mathematical performance at 24 months post-injury was mediated by Calculation at 2 months post-injury.

Overall, anxiety (child-rated or parent-rated) and family burden did not mediate the effect of group on Applied Problems or Calculation at either time point. For both Applied Problems and Calculation, mathematical performance at 2 months post-injury mediated the effect of group on mathematical performance at 24 months post-injury.

Hypothesis 4C: Heuristic for executive functioning, parent-rated anxiety, and family burden.

Applied Problems. The path analysis that examined the proposed heuristic (Figure 1) had poor fit: $\chi^2(15) = 93.775$, $p = 0.000$, CFI = 0.684, RMSEA = 0.216, SRMR = 0.147. However, the paths predicting Applied Problems at 24 months post-injury accounted for 71.1% of the variance. We then proceeded with exploratory analyses by examining the modification indices and by utilizing theory and knowledge of the variables. Specifically, we allowed the errors of the three parent-rated scales to correlate (3 df), and included mother's education as a predictor of Applied Problems at 2 months (1 df). The only substantive change was to include direct paths from group to executive functioning (2 df). This fuller model (see Figure 2) had good fit: $\chi^2(9) = 15.426$, $p = 0.080$, CFI = 0.974, RMSEA = 0.079, SRMR = 0.062, though with 6 fewer degrees of freedom. Similar to the hypothesized model, the model predicting Applied Problems at 24 months post-injury accounted for 71.3% of the variance. We then trimmed the model to evaluate the most parsimonious model that still exhibited good fit, and that was consistent with the results of hypotheses 4a and 4b. This trimmed model set the value of the non-significant direct effects on Applied Problems at 24 months post-injury (i.e., group, parent-rated anxiety at 24 months post-injury, and family burden at 24 months post-injury) to zero. The trimmed model also had good fit: $\chi^2(13) = 20.133$, $p = 0.092$, CFI = 0.971, RMSEA = 0.070, SRMR = 0.063. The Chi-square change between the final model and trimmed model was not significant, $\chi^2\Delta(4) = 4.707$, $p = 0.319$. The paths in the trimmed model which were predicting Applied Problems at 24 months post-injury accounted for 70.5% of the variance.

Calculation. The path analysis that examined the proposed heuristic (Figure 1) had poor fit: $\chi^2(15) = 86.613$, $p = 0.000$, CFI = 0.680, RMSEA = 0.206, SRMR = 0.136. However, the paths predicting Calculation at 24 months post-injury accounted for 64.0% of the variance. We then proceeded with exploratory analyses by examining the modification indices and by utilizing theory and knowledge of the variables. Specifically, we allowed the errors of the three parent-rated scales to correlate (3 df). The only substantive change was to include direct paths from group to executive functioning (2 df). This fuller model (see Figure 3) had fair fit*:* $\chi^2(10) = 18.455$, $p = 0.0478$, CFI = 0.962, RMSEA = 0.087, SRMR = 0.063, though with 5 fewer degrees of freedom. Similar to the hypothesized model, the model predicting Calculation at 24 months post-injury accounted for 63.7%of the variance. We then trimmed the model to evaluate the most parsimonious model that still exhibited good fit, and that was consistent with the results of hypotheses 4a and 4b.This trimmed model set the value of the non-significant direct effects on Calculation at 24 months post-injury (i.e., group, parent-rated anxiety at 24 months post-injury, and family burden at 24 months post-injury) to zero. The trimmed model had good fit: $\chi^2(14) = 21.832$, $p = 0.0821$, CFI = 0.965, RMSEA = 0.070, SRMR = 0.064. The Chi-square change between the final model and trimmed model was not significant, $\chi^2\Delta(4) = 3.377$, $p = 0.497$.The paths in the trimmed model which were predicting Calculation at 24 months post-injury accounted for 64.6% of the variance.

Discussion

The aim of the present study was to 1) investigate the change in executive functioning, anxiety, and family burden over two years post-injury following pediatric TBI compared to OI and to 2) explore the interplay of these factors and their predictive nature on mathematical performance at 24 months post-injury. The study sought to establish a foundation for future research to investigate a model of academic recovery after pediatric TBI. The major findings of the present study revealed that children with TBI had lower calculation and problem solving scores, as well as more executive functioning impairment compared to children with OI. Furthermore, executive functioning at 2 months partially mediated the effect of group on mathematical calculations at 2 months, while mathematical performance at 2 months mediated the relation of group on mathematical performance at 24 months. These findings highlight the adverse impact of disruption in executive functions shortly after TBI on calculation skills. Additionally, both the TBI and OI groups had high levels of child-rated anxiety at 2 and 12 months post-injury. Children with severe TBI had higher levels of family burden compared to children with OI at 12 and 24 months post-injury. Despite the high levels of anxiety and family burden, these variables did not significantly impact mathematical performance during the subacute stage of recovery or the development of mathematical skills during the first two years after TBI. In light of these findings, executive functions appear to play a specific and significant role in supporting fundamental calculation skills after TBI.

Executive functioning. The present study hypothesized that executive functioning would be at similar levels for children with TBI and OI at 2 months, but that children with TBI would increase in executive functioning difficulties and children with OI would decrease in executive functioning difficulties. The anticipated interaction was not significant; however, of note is that difficulties in executive functioning were higher for TBI than OI at all time points. This research solidifies the findings of previous studies demonstrating the long-standing executive functioning impairments in children with TBI (Anderson et al., 2009; Sesma et al., 2008; Yeates et al., 2002).

The mediation analyses emphasize the importance of executive dysfunction after brain injury. Executive functioning was a significant predictor of mathematical performance (Calculation) at 2 months post-injury, but not at 24 months post-injury. Arnet et al. (2013) found that executive functioning within 6 months post-injury uniquely predicted academic performance at 12 months post-injury in the context of other factors, such as injury severity, verbal memory, and family socioeconomic status. When comparing to the present study, it should be noted that Arnet et al. (2013) utilized parent-ratings of school competency as the outcome measure and utilized different time points in their analyses, which may account for the variability in findings. Despite differences from previous studies, the current study contributes to a discussion as to whether poor classroom performance after TBI is the result of difficulties with mathematical knowledge versus cognitive difficulties (e.g., executive functioning; Barnes, Fletcher, & Ewing-Cobbs, 2007). While the findings demonstrated that executive functioning was a significant mediator of the effect of group on Calculation at 2 months post-injury, this mediation was only partial and was not found for Applied Problems. Thus, poor classroom performance is likely multifactorial. Regardless, the present study suggests that knowing lower executive functioning performance at 2 months can serve as a red flag for evaluators that interventions and accommodations are needed to be implemented immediately after brain injury.

Although additional research is needed to document efficacy (Slomine & Locascio, 2009), cognitive rehabilitation and compensatory strategies need to be integrated into classroom instruction to support executive functions and mathematical learning after TBI. Thus, specific executive functioning supports and tools such as checklists, acronyms, templates, strategy notebooks, and checking for typical errors (Roditi & Steinberg, 2007) should be incorporated as part of mathematical instruction for children after TBI. Approximately 25 to 45 percent of children with moderate to severe TBI receive new academic support services at school through federal statutes and another 40 percent receive informal supports (Ewing-Cobbs et al., 1998; Glang et al., 2008, Rivara et al., 2012). Services and accommodations through schools should place a higher emphasis on structure and helping to improve and augment executive functioning soon after injury, which in turn may serve to help increase mathematical recovery. In sum, the present study demonstrates how critical of a role executive functioning plays on mathematical performance after brain injury, providing additional support for previous studies (Arnett et al., 2013; Raghubar et al., 2013).

Furthermore, executive functioning appears to operate differently for Applied Problems versus Calculation after pediatric TBI. Fuchs et al. (2008) found differences in specific cognitive functions that predict different mathematical skills, such that math computational skill was predicted by word identification, attention, processing speed, and working memory, while math problem solving was predicted by language, concept formation, nonverbal reasoning, working memory, and attention. The present study sheds light on how executive functioning difficulties after pediatric TBI impact different mathematical skills. The mediation models in the current study revealed that executive functioning influenced Calculation early in recovery (i.e., 2 months post-injury), while it did not appear to influence Applied Problems within 24 months of recovery. This finding is surprising given that more complex mathematics, such as word problems, would be expected to utilize more executive functioning skills than more than basic mathematical calculations. However, it may be that for Applied Problems children can rely on verbal abstract reasoning skills, whereas Calculation involves more specific math facts and procedures that may necessitate executive functioning skills.

Anxiety. The data shows little support for the hypothesis that anxiety would increase in the TBI group and decrease in the OI group from 2 to 24 months post-injury. Amongst the three groups, both parent and child-reported anxiety were similar at 2 months; however, over the course of 2 years, the level of parent-reported anxiety (but not child reported anxiety) decreased for both groups. The difference between child-reported and parent-reported anxiety was unsurprising given that previous research has demonstrated low correlations between parent- and self-rated anxiety (Langer et al., 2010; Manassis et al., 2009) and parental under-reporting of internalizing symptoms (Levi et al., 1999). Of note is the fact that both the TBI and OI groups exhibited high rates of child-rated anxiety after injury at 2, 12, and 24 months post-injury. This supports previous research demonstrating the continued rates of anxiety after injury in TBI (Bloom et al., 2001; Karver et al., 2012; Luis & Mittenberg, 2002; Max et al., 2011). Additionally, previous research has revealed high rates of anxiety in OI populations, with a substantial percentage meeting criteria for Acute Stress Disorder and Posttraumatic Stress Disorder (Holbrook et al., 2005; Kassam-Adams & Winston, 2004).

The findings of the present study signify the impact of injury on the emotional status of these children and highlight the need for psychological services after injury. Kassam-Adams, Marsac, Hildenbrand, and Winston (2013) discuss various levels of intervention following pediatric injury, including universal preventative interventions, targeted and indicated preventative interventions, as well as stepped care models. A preventative intervention that has been utilized for injured children is the D-E-F protocol (Stuber, Schneider, Kassam-Adams, Kazak, & Saxe, 2006). The notion for this intervention is that after providers have addressed the child’s airway, breathing, and circulation (ABC’s), then it is necessary to attend to the areas of distress, emotional support, and family. Preventative interventions used after pediatric injury have been found to reduce behavioral difficulties in younger children (Zehnder, Meuli, & Landolt, 2010), decrease levels of anxiety (Cox, Kenardy, & Hendrikz, 2009), and increase parental knowledge and assistance of their child’s symptoms (Marsac, Kassam-Adams, Hildenbrand, Kohser, & Winston, 2011). Additionally, targeted interventions such as psychoeducation and coping strategies have been found to be effective for children at risk for developing Posttraumatic Stress Disorder (Kramer & Landolt, 2011), while trauma-focused cognitive-behavioral therapy (TF-CBT) has been demonstrated as an effective treatment for children meeting criteria for Posttraumatic Stress Disorder (Cohen & Mannarino, 2008). However, these particular interventions have not been investigated within the context of children with TBI. In recent years, the implementation of online family-based problem-solving interventions following pediatric TBI has been investigated. Programs such as the Counselor-Assisted Problem Solving (CAPS) have demonstrated improvements in executive functioning (Kurowski et al., 2013, 2014), internalizing behaviors and depressive symptoms, and externalizing behavior problems (Wade et al., 2014; Wade, Walz, Carey, & Williams, 2008). While progress towards interventions for children after TBI has certainly been made, further research is necessary to provide ample support for the long-standing anxiety experienced by this population.

In terms of anxiety's predictive ability of mathematical performance, there were no significant mediation or path models demonstrating an impact of anxiety on mathematical performance after injury. Additionally, the measures of anxiety utilized in the present study assessed general levels of anxiety as opposed to math-specific anxiety. It may be that math anxiety has an impact on mathematical performance after TBI, whereas general anxiety does not. Thus future studies should explore the potential impact of math anxiety on recovery of mathematical skills after TBI. Lastly, the current findings reflect mathematical performance on standardized measures, rather than classroom mathematical performance, where anxiety might play a more prominent role. Mathematical performance in the classroom may be impacted by anxious thoughts derived from factors such as peer comparison, desire to please the teacher or parents, and the impact of test performance on grades.

Family burden. The present findings demonstrate partial support for the hypothesis that children with TBI and OI would have similar levels of family burden at 2 months, and that both groups would decrease in burden over the course of 24 months, with a greater decrease in the OI group. Children with severe TBI were found to have higher ratings of family burden at 12 and 24 months post-injury compared to controls. The anticipated group by time interaction was not significant. However, it is important to emphasize that families of children with TBI continue to have high rates of burden from the injury at 24 months post-injury. The levels of burden at 12 months post-injury found in the present study (complicated-mild/moderate TBI = 0.34, severe TBI = 0.68, OI = 0.25) are most consistent with the levels in Wade et al. (2006; approximate levels: moderate TBI = 0.40, severe TBI = 0.60, OI = 0.25), but slightly lower than those in Wade et al. (1998; moderate TBI = 0.62, severe TBI = 1.07, OI = 0.31). These findings support previous research (Wade et al., 1998, 2006) and demonstrate that children with severe TBI had higher rates of burden at 12 months post-injury and longer compared to OI controls. However, the levels of burden observed in the present study were lower than expected for the TBI group. The item responses from the FBII ranged from 0 (not at all stressful) to 4 (extremely stressful), and the average of applicable items was utilized in the study. Yet the highest value for this measure was found for the severe TBI group at 2 month post-injury, with a value of 0.85. Thus, while the values were relatively comparable to previous studies, it may be the case that caregivers were underreporting levels of burden.

Furthermore, unlike previous studies, the severe TBI group did not significantly differ in rates of burden from the complicated-mild/moderate TBI group. Additionally, the present study did not find an effect for time in which all groups significantly decreased in their ratings of family burden, consistent with the findings in Wade et al. (1998) that compared 6 months to 12 months post-injury. However, Wade et al. (2006) investigated a longer time comparison and found a significant time effect with all group decreasing in family burden from 1 year post-injury to 6 years post-injury. With respect to levels of burden amongst the groups, the present study found similar levels as previous research (Wade et al., 2006). Overall, the present findings emphasize the long-standing stressors experienced by families of children with TBI. Thus, it is vital that these families seek resources, such as support groups and utilize coping strategies.

Similarly to the current study's findings on anxiety, there were no significant mediation or path models revealing an impact of family burden on mathematical performance after injury. This was surprising given previous research that has demonstrated associations between high levels of family stress and poorer cognitive and academic performance in children with TBI (Max et al., 1999; Rivara et al., 1996; Taylor et al., 1999; 2002; Yeates et al., 1997). However, it should be noted that these previous studies generally evaluated family stress in terms of other aspects of the family environment (e.g., overall family functioning, social stressors, parental psychopathology), and none contained performance-based measures of mathematical skills. Taylor et al. (1999) did evaluate family burden which interacted with group to predict overall math skills, as well as teacher ratings of academic performance. The discrepancy in findings in the current study may be the result of utilizing different measures of family functioning and academic performance. It may be the case that other aspects of the family environment (e.g., parental coping, parental psychopathology, or family dysfunction) are more likely to influence aspects of academic recovery, including mathematical performance. Thus, future research is needed to further determine if other particular domains of the family environment influence mathematical recovery after TBI. Additionally, as previously mentioned, the levels of burden observed in the present study were lower than expected for the TBI group, which raises the question as to whether the construct was appropriately measured by the questionnaire and/or whether caregivers were underreporting. Thus, the lack of association with mathematical outcomes could potentially be the result of restriction of range. Future research will benefit from analyzing the FBII in various manners to determine if the construct is being appropriately measured. Despite the paucity of impact on mathematical performance found in the present study, family burden from the injury remains a crucial issue to address, as it may play a role on more general school functioning in the classroom, as well as the child's emotional functioning.

Heuristic. The proposed path analyses for predicting Applied Problems and Calculation at 24 months post-injury both had poor fit. However, it should be noted the paths accounted for 71.1% and 64.0% of the variance, respectively, and that the source of poor fit was largely non-substantive. The primary issue with the proposed path analyses was that for both mathematical outcomes, in order to produce a better fitting model, the errors of executive functioning at 24 months post-injury, parent-rated anxiety at 24 months post-injury, and family burden at 24 months post-injury had to be correlated with one another. This suggests that the poor fit of the hypothesized model was in part due to the fact that these variables were all based on parent report. Perhaps if measures of math-specific anxiety, physiological levels, or performance measures of executive functioning were utilized, then the proposed heuristic may have demonstrated better fit. By utilizing alternative measures derived from varying sources (parent-report versus performance measures), this may help to eliminate questions as to whether the constructs were appropriately measured. As mentioned previously, the proposed models had excellent prediction power, yet the parent-report measures were not substantially additive over mathematical performance at 2 months post-injury. Despite the current findings of the path analyses, executive functioning remains an important factor in mathematical recovery in line with prior research, as previously discussed. As for parent-rated anxiety and family burden, the present study did not demonstrate their impact on predicting mathematical outcomes; however, it may be that math-specific anxiety and other measures of familial stress after pediatric TBI play a potential role. Together, these results indicate that further research would benefit from determining what alternative measures should be implemented to predict mathematical outcomes and what other factors may account for the remaining variance in mathematical recovery after pediatric TBI.

Limitations and future directions. The current study had some limitations that may have impacted the findings. The sample size of the present study was relatively small, particularly when investigating differences between the levels of injury severity; however, the sample size was not unexpected given the longitudinal nature of the study. Additionally, the current study did not include a healthy comparison group. It is possible that the findings of the present study may have found different relations between the levels anxiety, family burden, and executive functioning and the mathematical outcomes if the TBI group was contrasted with a healthy comparison group that exhibited low levels of anxiety. Furthermore, the children with TBI that were excluded from analyses with mathematical outcomes (i.e., they did not complete mathematical measures at both time points), had higher rates of family burden at 12 and 24 months post-injury and lower Calculation scores at 24 months post-injury. It is possible that these families were unable to complete all aspects of the study due to high levels of burden from the injury, thus our findings may not appropriately reflect the real-world nature for some of these families.

Another potential limitation of the study was that the average mathematical scores for the severe TBI group at all time points fell within the Average range. This may have been the result of the particular participants that elected to be in the present study, but nevertheless, this likely had an impact on the relationships found between mathematical outcomes and the various predictors. Additionally, the child-reported anxiety measure (SCARED) was not administered at 24 month post-injury; however, the present study emphasized the presence of anxiety in not only children with TBI, but also OI, at one year post-injury. Furthermore, the present study utilized a global measure of executive functioning and child-rated anxiety in the analyses. Both the BRIEF and SCARED contain relevant subscales of interest (e.g., Working Memory and School Phobia, respectively) that may be useful to investigate in subsequent studies.

In addition to the ideas for future research previously mentioned, our knowledge would also benefit from extending the investigation of mathematical performance in pediatric TBI by including a measure of math-specific anxiety. This is relevant given that some studies have suggested that mathematical performance is only related to math-specific anxiety as opposed to general levels of anxiety (Ashcraft & Krause, 20007; Wu et al., 2012). Additionally, to date, no study of mathematical performance in pediatric TBI has evaluated other relevant math-related skills (e.g., math fluency, classroom performance) or the impact of math-specific anxiety. However, a strength of the current study was the use of parent and child ratings to predict test performance, as opposed to previous studies which encountered the problem of shared variance when using parent- or self-report measures as both predictors and outcome variables.

Moreover, extending the approach of the present study to other psychological domains, such as depression, would be beneficial for furthering our understanding of how emotional functioning impacts the recovery of mathematical skills and the acquisition of new skills following pediatric TBI. Future research exploring general family stress or other factors in the family environment, as opposed to burden related to injury, may also shed further light on the interplay of family factors on academic recovery over time in pediatric TBI. Lastly, while the high rates of child-rated anxiety and family burden were not found to be predictive of the mathematical measures in the current study, they may be related to everyday mathematical performance (i.e. classroom performance).

Conclusion. The present study on mathematical performance after pediatric TBI supported previous research demonstrating continued rates of anxiety after injury in both TBI and OI, high rates of burden from injury in families of children with TBI at 24 months post-injury, and long-standing executive functioning impairments in children with TBI. Our most notable finding was that executive functioning was a significant predictor of mathematical calculations at 2 months post-injury. This knowledge may serve as a red flag for evaluators that interventions and accommodations need to be implemented immediately after brain injury, particularly given that children with low mathematical performance and executive functioning difficulties are at risk for continued mathematical difficulties in the future. Moreover, these children are in jeopardy for poorer educational and vocational outcomes. Furthermore, while child-rated anxiety and family burden were not significant predictors of mathematical performance at 24 months post-injury, their high levels at 24 months post-injury are crucial for the awareness of medical, education, and psychological providers. These findings are particularly useful in terms of informing cognitive interventions, as well as providing therapy and resources to the families of both children with TBI and OI.

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Table 1. Demographic information by group.

Variable	Complicated-Mild/ Moderate TBI	Severe TBI	OI
	n = 13	*n* = 47	*n* = 55
Months of Age at Injury (*M* (*SD*))	133.00 (37.87)	136.02 (36.02)	123.02 (35.49)
Gender (% male)	62	79	60
Ethnicity (%)			
Caucasian	62	43	42
Hispanic	23	34	31
African American	0	15	20
Asian/Other	16	8	7
Handedness (% right)	92	79	85
Mother's Years of Education (*M* (*SD*))	12.69 (5.07)	12.77 (5.10)	14.35 (3.86)
Glasgow Coma Scale score at time of hospital admission (*n*)			
3-8	0	36	—
9-12	7	6	—
13-15	6	5	—
Mechanism of injury (*n*)			
Motor vehicle accident	6	26	6
Pedestrian struck by auto	0	14	10
Fall	4	6	21
Sports/Play	0	1	14

Note: TBI = traumatic brain injury; OI = orthopedic injury; M = mean; SD = standard deviation.

Table 2. Means, standard deviations, and effect sizes for variables of interest.

Variable	Complicated-Mild/ Moderate TBI Mean (SD)	Severe TBI Mean (SD)	OI Mean (SD)	Cohen's *d* (Complicated-Mild/ Moderate TBI vs. OI)	Cohen's *d* (Severe TBI vs. OI)
BRIEF General Executive Composite T Score*					
2 months	56.64 (10.54)	55.31 (13.84)	48.21 (8.08)	0.90	0.63
12 months	56.36 (12.99)	54.11 (10.16)	46.21 (7.97)	0.94	0.87
24 months	53.45 (9.55)	55.83 (12.04)	45.97 (9.14)	0.80	0.92
SCARED Total Raw Score					
2 months	21.31 (12.40)	24.98 (16.50)	25.96 (13.07)	-0.37	-0.07
12 months	23.62 (8.87)	22.08 (13.89)	23.83 (12.15)	-0.02	-0.13
CBCL Anxiety Problems T Score†					
2 months	54.64 (6.19)	56.64 (6.36)	55.84 (7.36)	-0.18	0.17
12 months	53.00 (3.90)	55.03 (6.05)	53.03 (5.96)	-0.01	0.33
24 months	53.27 (4.45)	55.72 (6.78)	52.50 (4.55)	0.17	0.56
FBII Average Raw Score**					
2 months	0.60 (0.75)	0.85 (0.77)	0.58 (0.66)	0.03	0.38
12 months	0.34 (0.33)	0.68 (0.66)	0.25 (0.35)	0.26	0.81
24 months	0.39 (0.52)	0.71 (0.63)	0.17 (0.25)	0.54	1.13
WJ-III Applied Problems Standard Score					
2 months	106.23 (12.35)	98.34 (14.95)	110.81 (12.03)	-0.38	-0.92
24 months	109.00 (14.22)	99.68 (13.66)	110.15 (11.84)	-0.09	-0.82
WJ-III Calculation Standard Score					
2 months	107.54 (15.76)	94.11 (14.84)	108.85 (10.76)	-0.10	-1.10
24 months	106.31 (14.99)	97.34 (14.53)	107.83 (10.18)	-0.12	-0.84

Note: TBI = traumatic brain injury; OI = orthopedic injury; SD = standard deviation; for BRIEF, Complicated-Mild/Moderate TBI (n = 11), Severe TBI (n = 36), and OI (n = 38); for SCARED, Complicated-Mild/Moderate TBI (n = 13), Severe TBI (n = 40), and OI (n = 48); for CBCL, Complicated-Mild/Moderate TBI (n = 11), Severe TBI (n = 36), and OI (n = 38); for FBII, Complicated-Mild/Moderate TBI (n = 8), Severe TBI (n = 31), and OI (n = 42); for WJ-III Complicated-Mild/Moderate TBI (n = 13), Severe TBI (n = 38), and OI (n = 47); Clinically significant levels: BRIEF ≥ 65, SCARED ≥ 25, and CBCL ≥ 65. Statistically significant findings: *group effects where severe TBI > complicated-mild/moderate TBI > orthopedic injury and ** where severe TBI > orthopedic injury; †Time effect where 2 months > 12 and 24 months.

Table 3. Correlation matrix between variables of interest for children with TBI.

	Age of Injury	Mother's Education	BRIEF 2 mo	BRIEF 12 mo	BRIEF 24 mo	SCARED 2 mo	SCARED 12 mo	CBCL 2 mo	CBCL 12 mo	CBCL 24 mo	FBII 2 mo	FBII 12mo	FBII 24 mo	WJ-III AP 2 mo	WJ-III AP 24 mo	WJ-III Calc 2 mo	WJ-III Calc 24 mo
Age of Injury	—																
Mother's Education	-0.06	—															
BRIEF 2 mo	0.00	0.14	—														
BRIEF 12 mo	0.20	0.03	0.42**	—													
BRIEF 24 mo	0.16	0.09	0.42**	0.74***	—												
SCARED 2 mo	-0.54***	-0.19	-0.04	-0.07	-0.05	—											
SCARED 12 mo	-0.41**	-0.05	0.05	-0.05	-0.01	0.60***	—										
CBCL 2 mo	-0.05	0.27	0.45**	0.24	0.48**	0.01	0.04	—									
CBCL 12 mo	0.20	0.25	0.39**	0.37**	0.46**	-0.16	-0.07	0.42**	—								
CBCL 24 mo	0.09	0.07	0.33*	0.37**	0.62***	0.14	0.05	0.48**	0.58***	—							
FBII 2 mo	0.11	0.10	0.37*	0.19	0.22	-0.18	-0.36*	0.27	0.45**	0.34*	—						
FBII 12 mo	0.28*	0.19	0.43**	0.50**	0.45**	-0.07	-0.04	0.36*	0.45**	0.42**	0.64***	—					
FBII 24 mo	0.23	0.24	0.51**	0.39**	0.52***	-0.08	0.00	0.41**	0.58***	0.60***	0.75***	0.86	—				
WJ-III AP 2 mo	-0.09	0.31*	-0.08	-0.06	-0.03	-0.23	0.02	-0.11	0.05	-0.15	-0.06	-0.11	-0.09	—			
WJ-III AP 24 mo	-0.23	0.23	0.01	-0.20	-0.22	-0.15	-0.01	-0.09	-0.03	-0.28*	-0.10	-0.32*	-0.30*	0.84***	—		
WJ-III Calc 2 mo	-0.01	0.22	-0.19	-0.11	-0.10	-0.34*	-0.22	-0.20	-0.15	-0.28*	-0.14	-0.12	-0.14	0.71***	0.76***	—	
WJ-III Calc 24 mo	-0.11	0.15	-0.15	-0.15	-0.15	-0.11	-0.10	-0.04	-0.05	-0.31*	-0.24	-0.36**	-0.41**	0.70***	0.80***	0.81***	—

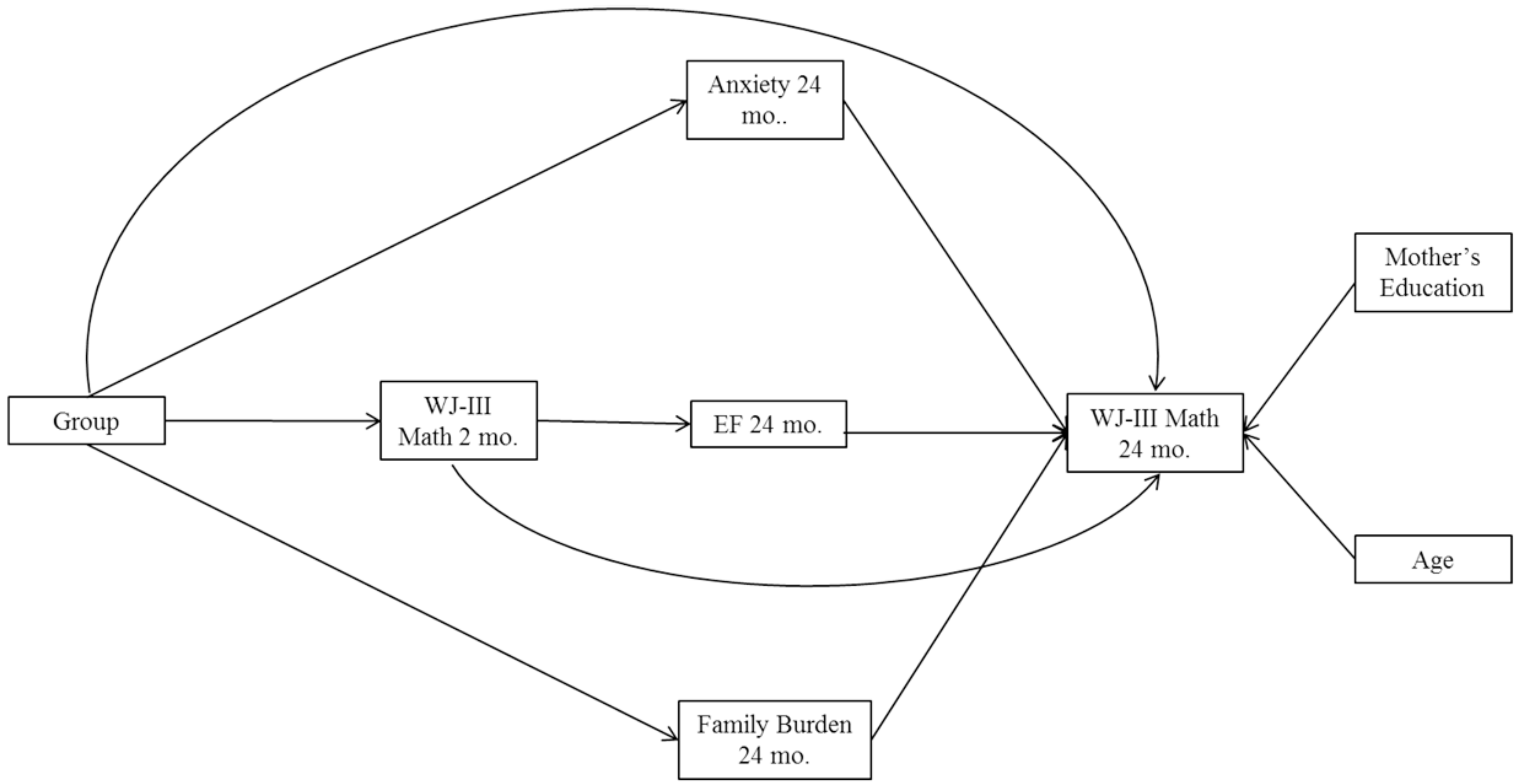
Note: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.0001$; mo = months post-injury; BRIEF = BRIEF General Executive Composite T Score; SCARED = SCARED Total Raw Score; CBCL = Child Behavior Checklist Anxiety Problems T Score; FBII = Family Burden of Injury Interview Average Raw Score; WJ-III = Woodcock-Johnson III; AP = Applied Problems; Calc = Calculation.

Table 4. Mediation models of group effects on mathematical outcomes: Indirect effects.

Math Outcome *Mediator*	Point Estimate	95% Bootstrap CI
Applied Problems at 2 months		
Executive Functioning at 2 months	-0.44	-1.37 to 0.05
Applied Problems at 24 months		
Executive Functioning at 24 months	-0.35	-1.23 to 0.11
*Applied Problems at 2 months**	-3.92	-6.10 to -1.91
Calculation at 2 months		
*Executive Functioning at 2 months**	-0.71	-1.93 to -0.06
Calculation at 24 months		
Executive Functioning at 24 months	0.02	-0.54 to 0.60
*Calculation at 2 months**	-4.83	-7.23 to -2.68
Applied Problems at 2 months		
Child-rated Anxiety at 2 months	-0.21	-1.33 to 0.79
Family Burden at 2 months	-0.25	-1.18 to 0.10
Applied Problems at 24 months		
Child-rated Anxiety at 24 months	-0.03	-0.48 to 0.14
Family Burden at 24 months	0.00	-0.88 to 0.71
*Applied Problems at 2 months**	-3.39	-5.94 to -1.36
Calculation at 2 months		
Child-rated Anxiety at 2 months	-0.17	-1.22 to 0.59
Family Burden at 2 months	-0.34	-1.70 to 0.14
Calculation at 24 months		
Child-rated Anxiety at 24 months	-0.05	-0.68 to 0.15
Family Burden at 24 months	-0.22	-1.37 to 0.67
*Calculation at 2 months**	-4.91	-7.87 to -2.79
Applied Problems at 2 months		
Parent-rated Anxiety at 2 months	-0.05	-0.86 to 0.27
Family Burden at 2 months	-0.22	-1.37 to 0.11
Applied Problems at 24 months		
Parent-rated Anxiety at 24 months	-0.30	-1.09 to 0.03
Family Burden at 24 months	0.33	-0.43 to 1.28
*Applied Problems at 2 months**	-3.83	-6.50 to -1.74
Calculation at 2 months		
Parent-rated Anxiety at 2 months	-0.03	-0.97 to 0.38
Family Burden at 2 months	-0.39	-1.84 to 0.13
Calculation at 24 months		
Parent-rated Anxiety at 24 months	-0.08	-0.90 to 0.31
Family Burden at 24 months	-0.35	-1.66 to 0.90
*Calculation at 2 months**	-3.01	-5.34 to -1.38

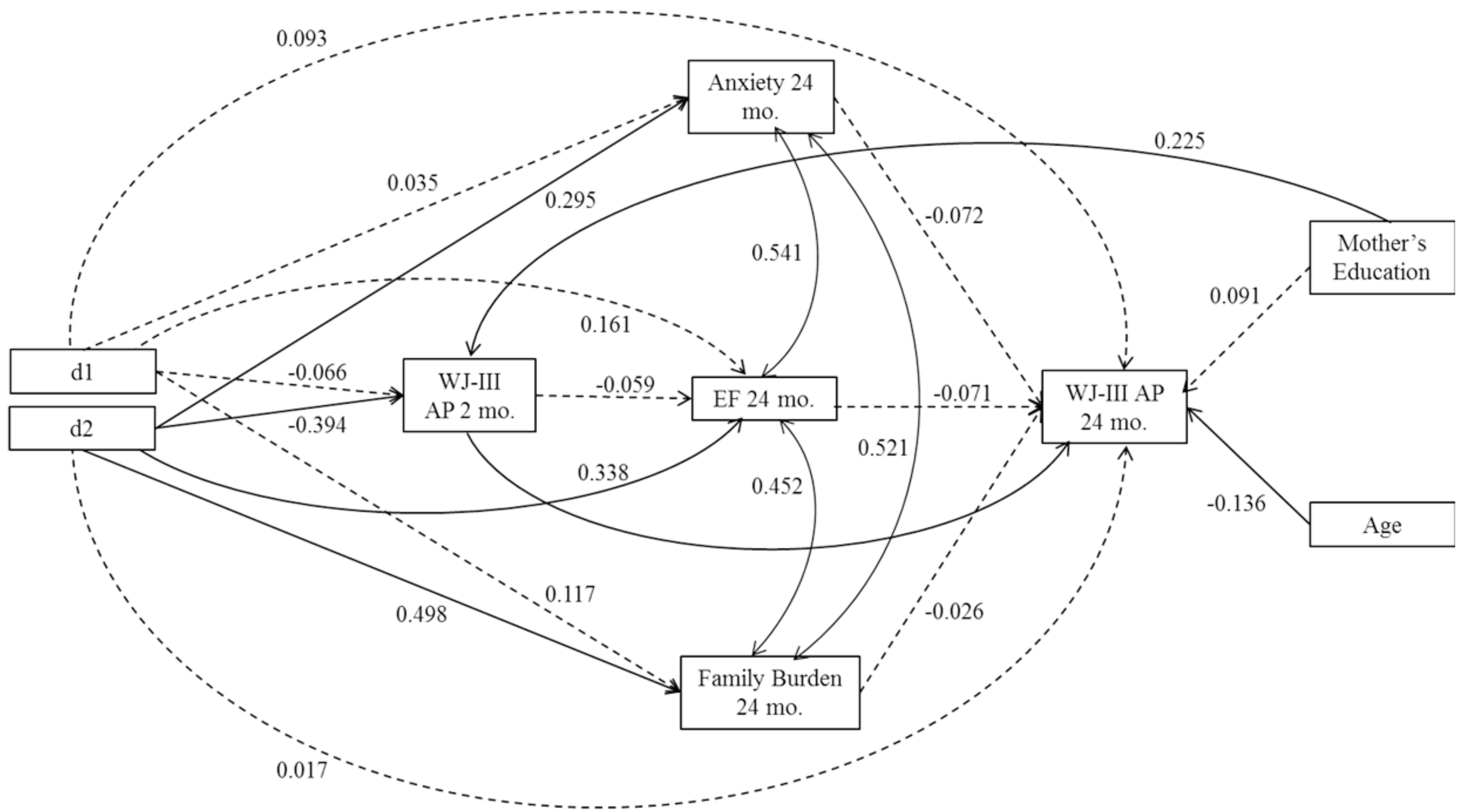
Note: Variables in italics represent mediators between group and mathematical outcomes; The point estimates are given for each mediator within the context of the other mediators for each analysis;*Significant mediator; CI = Confidence Interval.

Figure 1. Proposed path analysis of the effect of group on mathematical performance at 24 months post-injury.



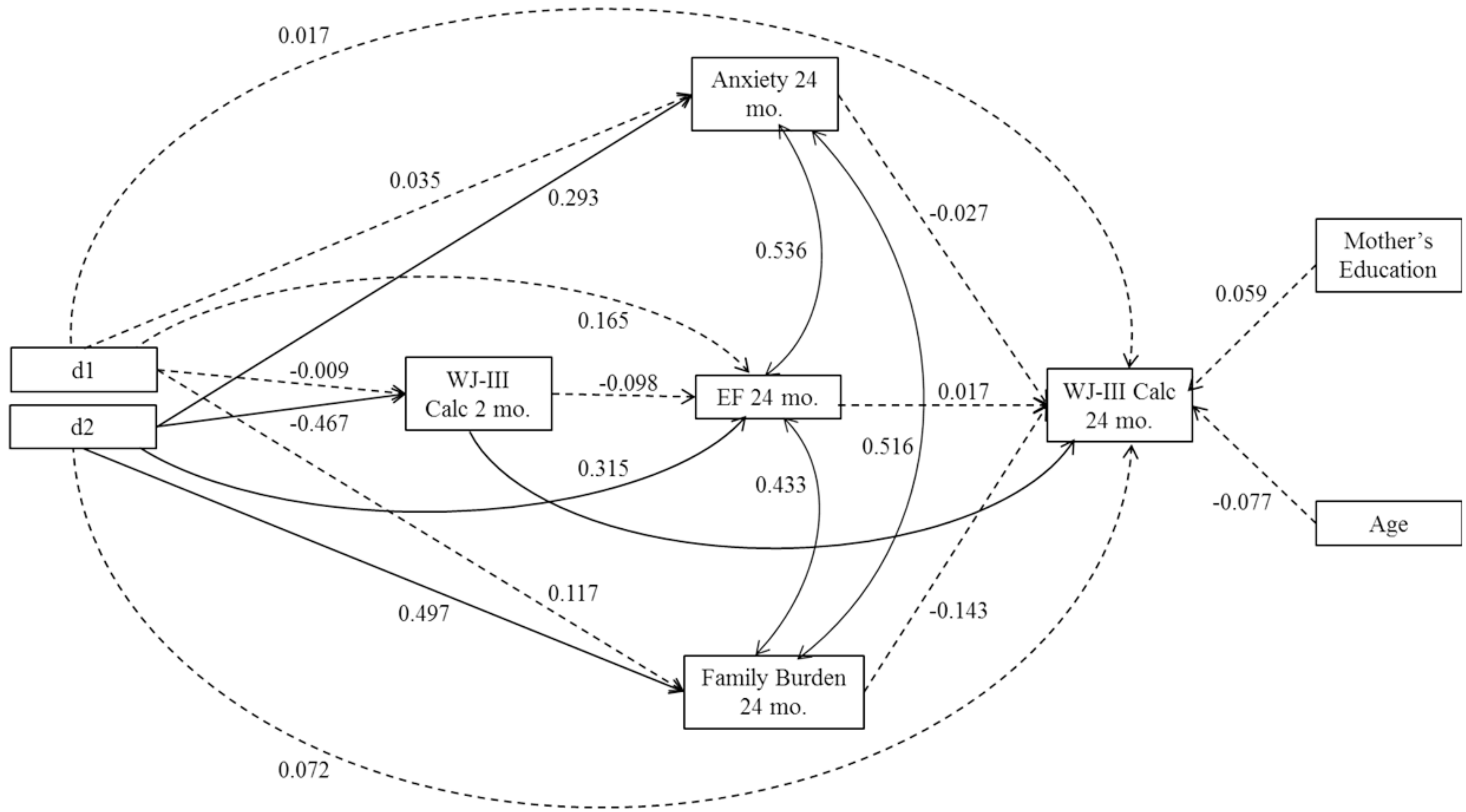
Note: Figure reveals proposed heuristic only; Executive functioning is predicted to mediate the effect of mathematical performance at 2 months on mathematical performance at 24 months; Group and mathematical performance at 2 months have both direct and indirect effects on mathematical performance at 24 months; Group = Complicated-Mild/Moderate TBI, Severe TBI, OI; WJ-III = Woodcock-Johnson III; EF = Executive Functioning.

Figure 2. Full path analysis of the effect of group on Applied Problems at 24 months post-injury.



Note: $\chi^2(9) = 15.426$; $p = 0.080$; CFI = 0.974; RMSEA = 0.079; SRMR = 0.062; R^2 (AP 24 months) = 71.3%; Dashed lines indicate non-significant paths; Path weights are standardized; Double-arrow lines indicate error correlation; Standard errors are not reported to enhance reader's viewing; Group = Complicated-Mild/Moderate TBI, Severe TBI, OI; WJ-III = Woodcock-Johnson III; EF = Executive Functioning; AP = Applied Problems.

Figure 3. Full path analysis of the effect of group on Calculation at 24 months post-injury.



Note: $\chi^2(10) = 18.455$; $p = 0.0478$; CFI = 0.962; RMSEA = 0.087; SRMR = 0.063; R^2 (Calc 24 months) = 63.7%; Dashed lines indicate non-significant paths; Path weights are standardized; Double-arrow lines indicate error correlation; Standard errors are not reported to enhance reader's viewing; Group = Complicated-Mild/Moderate TBI, Severe TBI, OI; WJ-III = Woodcock-Johnson III; EF = Executive Functioning; Calc = Calculation.